THE EFFECT OF FORMATIVE ASSESSMENT IN 11TH GRADE PHYSICS

by

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A professional paper submitted in partial fulfillment

of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2020

STATEMENT OF PERMISSION TO USE

In presenting this professional paper in partial fulfillment of the requirements for a master's degree in Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

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INTRODUCTION AND BACKGROUND

I teach physics and AP Environmental Science at Naperville North High School, a large suburban high school in Naperville, IL. This is our school's third year of Professional Learning Communities (PLCs). I am a part of a physics PLC and we meet once a week, on Wednesdays, for one hour. My PLC consists of a team of three teachers and myself. Our students have late arrival every Wednesday so that our PLCs can meet before school without any other potential obligations or conflicts. A primary focus of our work in PLCs is to design formative assessments and to use the results to create interventions, and eventually extensions, for students. For this school year, we were focused on the intervention piece. The full PLC cycle involves:

1. Identifying what students should learn, which may be content-based or skill-based
2. Instruction
3. Assessing whether or not students have learned the content or skill, usually through formative assessment
4. Sorting students into two groups: proficient or needs intervention
5. Implementing an intervention with those students who did not show proficiency

One hour each week, a large sum of time is devoted to this process. There is additional work to be completed on the teachers' part and, consequently, the process takes instructional time away from students. Since we are investing so much time in this process, I saw an opportunity for a research project.

Students have asked me "what do teachers do in those meetings?" on several occasions. I began to recognize that there was a disconnect between what we were doing as teachers and how it was being perceived by students. The average student might view the whole process as simply teachers creating an extra worksheet for them to complete in class every few weeks. I wanted to bridge that gap in their perceptions and make students a part of this process. This is how my research project came into action.

I chose to explore an aspect of my two physics classes for this project for several reasons. First, I have more experience teaching physics and, therefore, felt more comfortable with experimenting with something new. Second, the curriculum for the AP Environmental Science course was going through several changes as we worked to align our school's curriculum with the other high school in the district. This would make planning and experimentation more difficult, especially when trying to stay on pace with the other teachers teaching the course.

The combination of my experience teaching physics and the opportunity for collaboration with my PLC led me to explore how formative assessments are used in physics. My primary research question is "what effect do formative assessments have on students' self-confidence, ownership of the material, and retention?" The sub-questions are:

1. How do formative assessments affect student confidence levels going into the summative assessment?
2. How do formative assessments affect how often students access help outside of the classroom?

3. How do formative assessments affect students' retention of class content?
4. How does using formative assessments impact me as the teacher?

The first sub-question was related to students' confidence. Throughout the past four years, I have seen students struggle with unhealthy stress levels and intense pressure to earn high grades. That is why my first research question examines improving students' confidence for summative assessments through the use of formative assessments, as this is something with which I felt I really needed to help my students.

The second sub-question looks at students accessing physics help outside of class. There are many places students can go to get academic help at Naperville North in general, but especially for physics. There is physics morning help every day before school, peer tutors for physics every day during all lunch hours, and after school tutoring two days a week. All of these options are in addition to teachers meeting before school, during lunch, and after school with their students. I noticed that my students were not taking advantage of the various resources that are available to them on a daily basis. Through the use of formative assessments, I decided I could be more explicit with individual students by giving specific recommendations based on each student's needs and personality.

The third sub-question focuses on retention of class content. I wanted to promote a deeper understanding for my students, and I thought it would be interesting to see how the PLC process and the use of formative assessments plays a role in that knowledge.

Finally, in the context of my research, a formative assessment was a check for understanding prior to the summative assessment. Students worked quietly and independently in class to complete these and I collected them and gave extensive feedback before returning them to students. There was nothing entered in the gradebook for these formatives, so they were not tied to students' grades in any way. I wanted to explore how this process could affect the classroom environment from the teacher's point of view

My support team for this project included several individuals. My content advisor was Walt Woolbaugh and my science reader was Megan Hopkins. My proofreader was Karen Quinn.

CONCEPTUAL FRAMEWORK

In searching through literature, I was able to use ideas I acquired from multiple sources to guide my work. My plan relied heavily on the feedback I would be giving students through formative assessments, as I imagined this was the core of my research project from which everything else stemmed. Therefore, I researched previous studies that provided information about formative assessment throughout history as well as the characteristics of effective formative assessments.

Formative assessments are not a new trend in education. Formative assessments have been used for multiple purposes throughout time, the term itself tracing back to the 1960's. Bell and Cowie (2001) point out that an early use of the term formative assessment was to differentiate between the assessments given by teachers in the classroom and assessments given by external examiners, such as with standardized

testing. This type of formative assessment has also been coined "weak formative assessment" (Brown, 1996). In the 1990's, formative assessments gained international popularity as multiple purposes for assessment became important. These multiple purposes included the auditing of schools, national monitoring, school leaver documentation, awarding of national qualifications, appraisal of teachers, curriculum evaluation, and the improvement of teaching and learning. Multiple purposes for assessment were further clarified by the National Research Council in 1999. Their abbreviated list included: to monitor educational progress or improvement, to provide teachers and students with feedback, and to drive changes in practice and policy by holding people accountable for achieving the desired reforms (National Research Council, 1999, pp.1−2).

Black and William (1998) begin their discussion of formative assessments by stressing the importance of teachers being flexible in their teaching by responding to student needs. As demonstrating flexibility and responsiveness is one of the criteria by which I am evaluated as a teacher, I see great value in using formative assessments as a way to be responsive to my students. Black and William's article states that the main difference between assessment and formative assessment is that formative assessment involves a teacher adapting to what his or her students need. The authors of this article establish their credibility by pointing out their extensive research related to formative assessment. Their findings ultimately show that 1. There is evidence that improving formative assessment raises standards, 2. There is room for improvement and 3. There is evidence about how to improve formative assessment. Black and William also show that formative assessments are able to narrow achievement gaps between low and high

performing students. Overall, this article outlined the importance of formative assessment and its ability to increase student achievement.

It is clear that practice and feedback are key components in students' acquisition of skills. Formative assessments allow for this and also promote self-reflection for students. According to Pellegrino, Chudowsky, and Glaser (2001), "one of the most important roles for assessment is the provision of timely and informative feedback to students during instruction and learning so that their practice of a skill and its subsequent acquisition will be effective and efficient" (p. 87). They also discuss that the lack of formative assessment is an ongoing dilemma in education. My project aimed to provide students with formative assessments and timely and informative feedback.

Sadler (1989) provided specific conditions for feedback to be useful for students. His first point was that students must know what good performance is. In terms of my project, that would mean my students understanding the learning standard. The second condition is that students must know how current performance relates to stronger performance on future assessments. The third and final condition is that students must know how to close the gap between current performance and future assessment performance. My students were given several options for where to get extra help and given individual suggestions on how to close that gap, if applicable.

A study of a formative assessment professional development program by Sondergeld et al. (2010) involved 65 teachers and their students. All teachers taught in K-8 buildings and engaged in a two year interactive professional development program on formative assessment. The program's organizing principle was "students and teachers

using evidence of learning to adapt teaching and learning to meet immediate learning needs minute-to-minute and day-by-day" (Thompson & Wiliam, 2007, p. 6). Formative assessment strategies were presented in introductory workshops. Teachers met long term over the course of the two years in teacher learning communities to work collaboratively to adopt and implement the formative assessment strategies. The results show that 82% of participating teachers reported various positive impacts on their students. More specifically, 69% of teachers saw increases in student participation and 40% saw their students take more ownership for their learning. This study showed the benefits of schools supporting teams of teachers in implementing formative assessments. For my project, I had other physics teachers in my PLC review and provide feedback on the formative assessments that were used. This gave my project a similar aspect of team collaboration.

Kingston and Nash (2011) issued a journal publication that reviewed over 300 studies that appeared to address the efficacy of formative assessment in grades K-12. In a meta-analysis, the impact of formative assessments on student achievement was assessed. Table 4 (p. 34) shows that formative assessment in science was less effective than mathematics or English, with English being the most effective of the three. These results are further interpreted as, "Perhaps ELA tasks, especially reading tasks, are more familiar to students and less cognitively complex than math or science tasks, which may help explain why this content area produced the largest mean effect size" (p. 33). I can connect this to my own teaching because I have given formative and summative assessments in different formats and I have seen how students can struggle with the way information is presented even if they have a strong grasp of the material. This research is

helpful for my action research because I want to ensure that the way I am assessing students is not foreign or too cognitively complex.

Overall, the research indicates that formative assessments are effective and have great potential in the classroom. There is a need for students to practice their skills and get timely feedback and for teachers to use data to guide their instruction. Through my project, my primary goal was to increase my students' understanding of physics concepts through the use of these positive learning experiences throughout a unit.

METHODOLOGY

Research Treatment

My research took place during the first semester of the 2019-2020 school year. I used my seventh and eighth period physics classes to determine the effect of formative assessments on students' self-confidence, ownership of the material, and retention. I used seventh period as the treatment group and eighth period as the non-treatment group first, and then switched and had seventh period as the non-treatment group and eighth period as the treatment group.

For the treatment group, I used teacher-designed formative assessments to provide timely feedback to students. These formative assessments were given as a supplement to the regular practice and feedback that students get during class. My feedback to students in the treatment group focused on general concepts and relationships that could be applied to other scenarios. For example, when giving feedback to a student on a question where they were asked to circle Newton's third law force-pairs, I reiterated how to find Newton's third law force-pairs in general. Based on my knowledge of my students, I also

gave suggestions for their next steps. For some students, this meant coming in for help outside of class, whereas some students received a reminder of specific additional resources on Canvas, our learning management system. Students' scores for this formative assessment were not entered in the gradebook.

Our physics class uses standards based grading. There are no traditional tests, but rather there are two "standards quizzes" on each learning standard. The first quiz on a standard, called pass one, is usually more elementary. Students will get feedback on pass one before they take the second quiz on the same standard, which is called pass two. Both quizzes for a standard are weighted the same so a student's overall grade for each standard is the average score of the two quizzes. These quizzes are graded on a four point scale, and students are able to retake these quizzes if they score below a certain percentage. I administered the formative assessment to the treatment group only before the quiz on pass one for a standard.

The timeline for the treatment group needed to incorporate two important features. First, I had to give the formative assessment after all of the content on pass one was covered in class. Secondly, students needed to have ample time to internalize and act on their feedback before the quiz. Therefore, this cycle took approximately six days.

I used the Balanced Forces unit for my treatment. The first standard in this unit is "I can identify force as an interaction between a pair of objects" and my seventh period class was the treatment group for this standard, meaning they received the teacher-designed formative assessment. The second standard in this unit is "I can distinguish between balanced and unbalanced forces and how they relate to the motion of a system" and my eighth period class was the treatment group for this standard.

Student Sample

My research was conducted with my general physics classes at Naperville North High School in Naperville, Illinois. In 2019, the school's total enrollment was 2,674 students. In the same year, there were 15.3% low income students at the school which is immensely lower than the number of low income students in the state, which was 48.8% (Illinois State Board of Education, 2019). With this being said, most of my students were from middle to upper middle class families. My seventh period class consisted of 28 students, 17 of which were males and 11 of which were females. Twenty six of these students were juniors and two were seniors. One student in the class had a 504 plan for ADHD and anxiety disorder. My eighth period class consisted of 20 students, three of which were males and 17 of which were females. Nineteen of these students were juniors and there was one senior. Two students had 504 plans, one for ADHD and one for ADHD, anxiety disorder, and headaches. Two students had IEPs, both related to reading comprehension and written expression.

Both physics classes had already finished the first full unit of learning, Constant Velocity, before this project started. Each unit in physics follows a similar pattern. We start with a paradigm lab, which is an informal learning lab. Students work in groups with teacher guidance and support. This is graded for completion only. The conclusions from the paradigm lab are typically presented through lab group whiteboards and summarized afterwards as a class. We revisit and build upon the key concepts from the paradigm lab throughout the rest of the unit.

In terms of class materials, each student has a physics workbook, which covers the entire first semester. Throughout the unit, students take notes and complete homework pages in their workbooks. There is no textbook for the class, so the workbook is where students keep most of their class materials. There are lab investigations that take a day or two throughout the units, and each student has a lab notebook where they keep lab materials. Standards quizzes are administered throughout the unit. At the conclusion of each unit, students work in groups to complete a lab practical. This is a summative assessment and each student turns in their own copy. A majority of the lab is completed collaboratively, but there is typically an independent portion as well.

Instrumentation

I used a variety of data collection instruments to investigate the effect of formative assessment with my physics classes, which produced both quantitative and qualitative data. Some of these instruments include surveys, teacher field notes, school tutoring logs, post-test data, quiz scores, and a teacher journal. These instruments are presented in Table 1.

Table 1
Triangulation Matrix of Data Collection Instruments for Research Questions

Research Question	Data Source(s)
#1: Student Self-Confidence	Student Surveys
	Classroom Observation– Field Notes
#2: Help Outside the Classroom	Student Surveys
	Logs of school tutoring data
	Post-test data

#3: Retention of class content	
	Quiz score on second pass
#4: Teacher Takeaways	Teacher Journal

Student surveys were used to collect data on student self-confidence the day of an in-class assessment for the treatment groups (Appendix A). The format was a 5 point Likert survey where students selected whether they agreed or disagreed, and to what extent, with a series of statements I provided. After receiving feedback from my research team, I decided to ask an open ended question asking students to explain their answer after each statement. This provided additional qualitative data for the first research question.

I was also able to use my field notes to monitor students' self-confidence. There are a large number of students at my school that struggle with test anxiety, and I've seen many examples of how this can affect students. Monitoring the classroom environment allowed me to look at students' confidence from another angle. Student surveys were also used for students to reflect on what type of help they sought before the quiz (Appendix B). I used check boxes to ask students to select all help centers they have visited. This also reinforced the different places students had available to them for future reference. Again, I asked students to briefly explain why or why not each help center was used because it was suggested that I could gather additional qualitative data this way. I received weekly school emails of student attendance so I could cross reference where students said they went with the school's documentation of these visits.

For retention of class content, I was able to look at this both short-term and long-term. The pass two quiz for both standards: "I can identify force as an interaction between a pair of objects" and "I can distinguish between balanced and unbalanced forces and how they relate to the motion of a system", can be found in Appendix C. For long term retention, I gave a post-test second semester (Appendix D). My students changed from first semester to second semester and I had seven students carry over that took the post-test.

Finally, I used a teacher journal to self-reflect on the takeaways from the teacher's point of view. My journal prompts can be found in Appendix E.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board (Appendix F) and compliance for working with human subjects was maintained throughout the course of the study.

DATA AND ANALYSIS

Figure 1
Analysis of Student Responses: Confidence for Summative Assessment

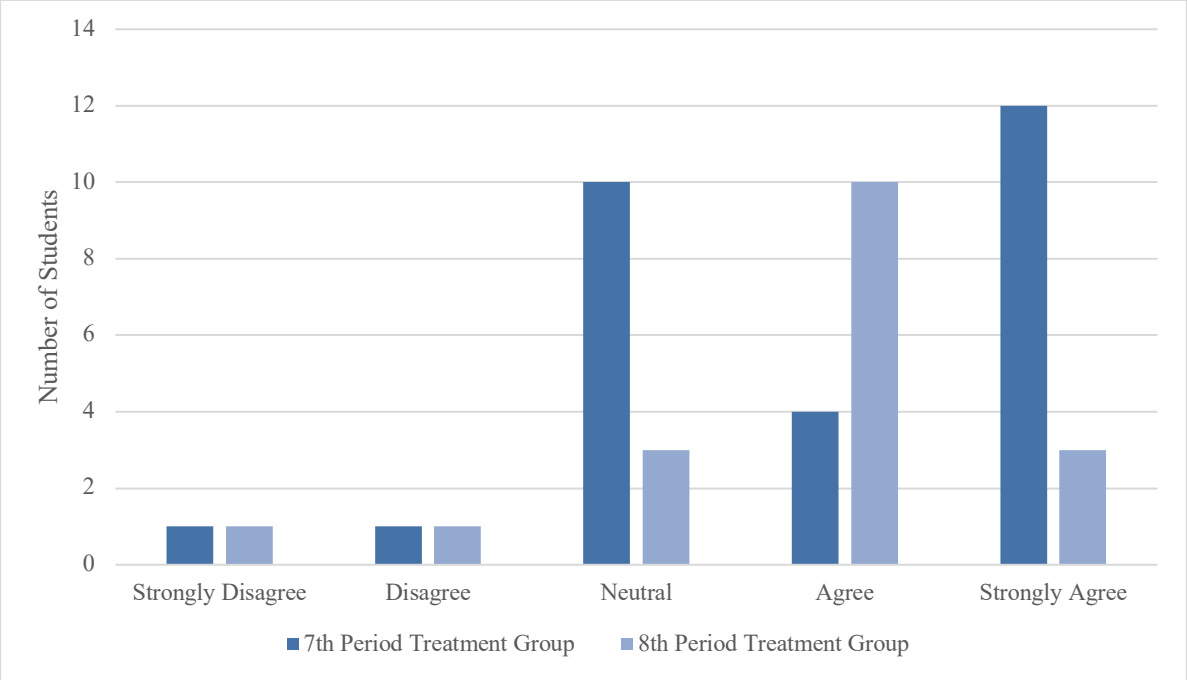

Figure 1 shows student responses to the survey question given right before taking the in class, summative assessment. The question stated, "I feel prepared for the standards quiz". The data shows that students in both the seventh period treatment group and eighth period treatment group had high levels of confidence right before taking their assessment. However, my observations show that the students who worry and/or get test anxiety were unaffected by this treatment. Fifty seven percent of the seventh period treatment group agreed or strongly agreed that they felt prepared for the quiz on the first balanced forces standard, "I can identify force as an interaction between a pair of objects". There were three students who specifically mentioned the formative assessment in their responses. Student 1 indicated that he agreed with the statement and went on to write, "Because I knew what I did wrong on the formative". Student 2 strongly agreed with the statement and wrote, "I am prepared because I

studied using my materials and feedback from the formative". Student 3 also strongly agreed and wrote, "Because I did well on the formative".

Eighth period saw higher numbers of students feeling confident. Seventy three percent of students in the eighth period treatment group agreed or strongly agreed that they felt prepared for the quiz on the second balanced forces standard, "I can distinguish between balanced and unbalanced forces and how they relate to the motion of a system". There were two students who mentioned the formative assessment for this survey question. Student A said she agreed with feeling prepared and wrote, "Got feedback back". Student B strongly agreed that she felt prepared and wrote, "I did good on the formative and looked over the practice problems". The only students that mentioned how the formative assessment affected their confidence were students who felt prepared. This shows that students were likely not negatively impacted by the formative assessment; rather, they didn't feel confident for other reasons.

Figure 2
Analysis of Student Help Visits Before Quiz One (N=15)

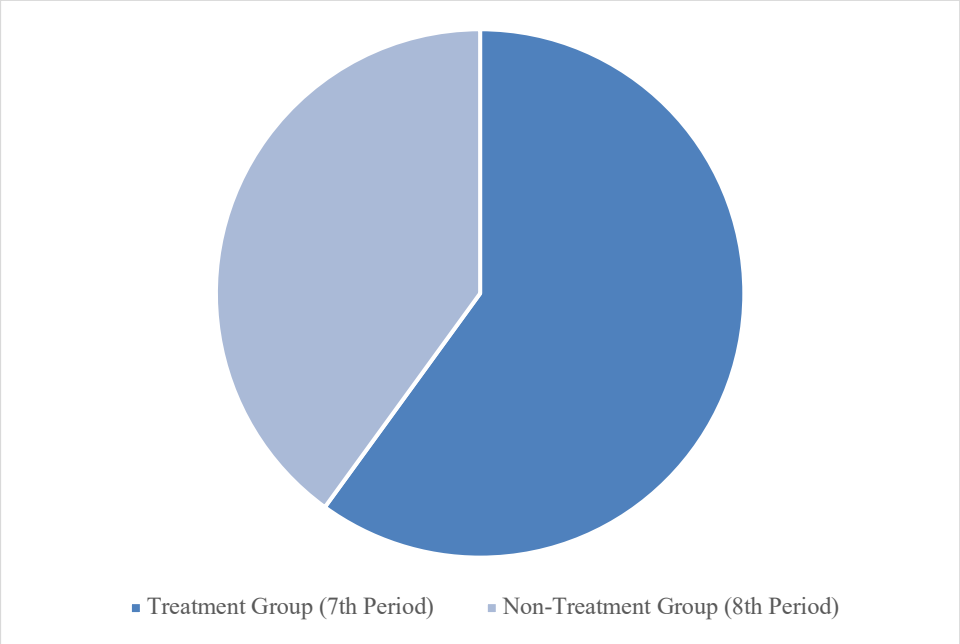

Figure 2 shows that before the first quiz, there were a total of 15 visits for extra help, with most students being from the treatment group.

Figure 3
Analysis of Student Help Visits Before Quiz Two (N=9)

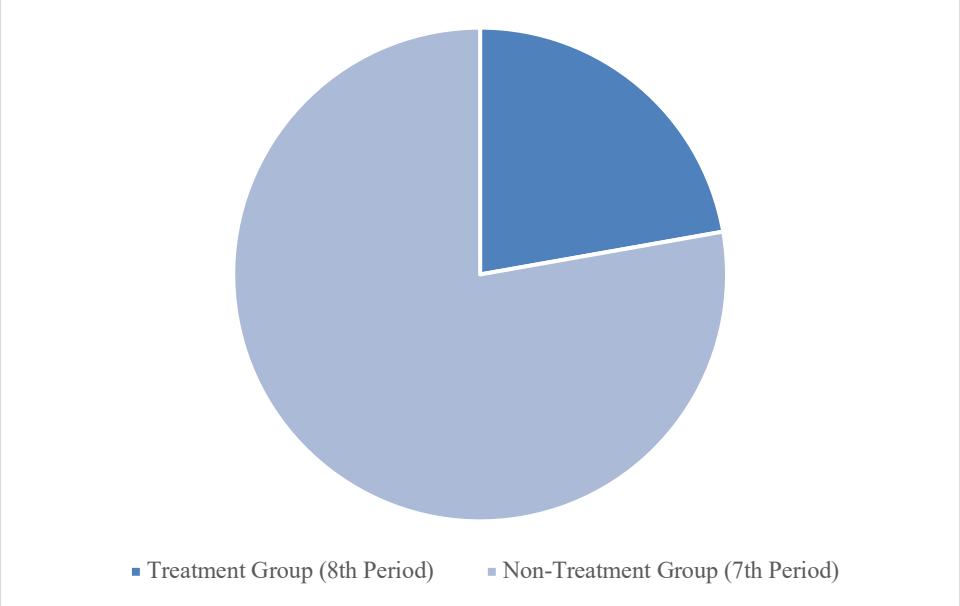

Figure 3 shows that before the second quiz, there were a total of nine visits for extra help, with most students being from the non-treatment group.

After a closer look, every student in seventh period who went in for extra help as part of the non-treatment group also went in for help as part of the treatment group. Also, both of the two students in eighth period who sought extra help as part of the treatment group also sought help as part of the non-treatment group. This shows that there was no relationship between the treatment and students accessing help outside of class. This shows that although students were recommended to seek physics help, some students did not have time or did not have the desire to go.

Figure 4
Quiz Scores on Standard One Pass Two

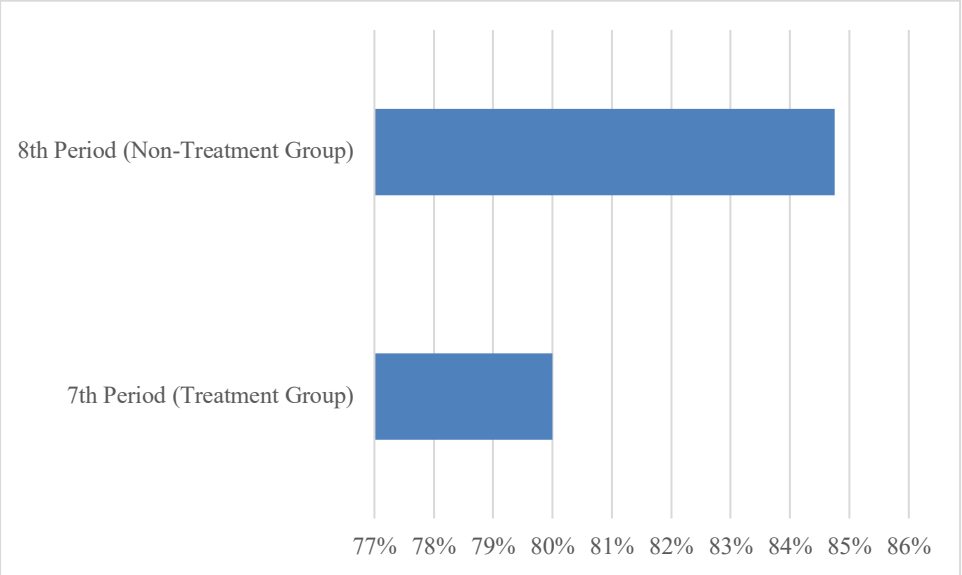

Figure 4 shows that students in the non-treatment group scored 4.75% higher than students in the treatment group on standard one pass two.

Figure 5
Quiz Scores on Standard Two Pass Two

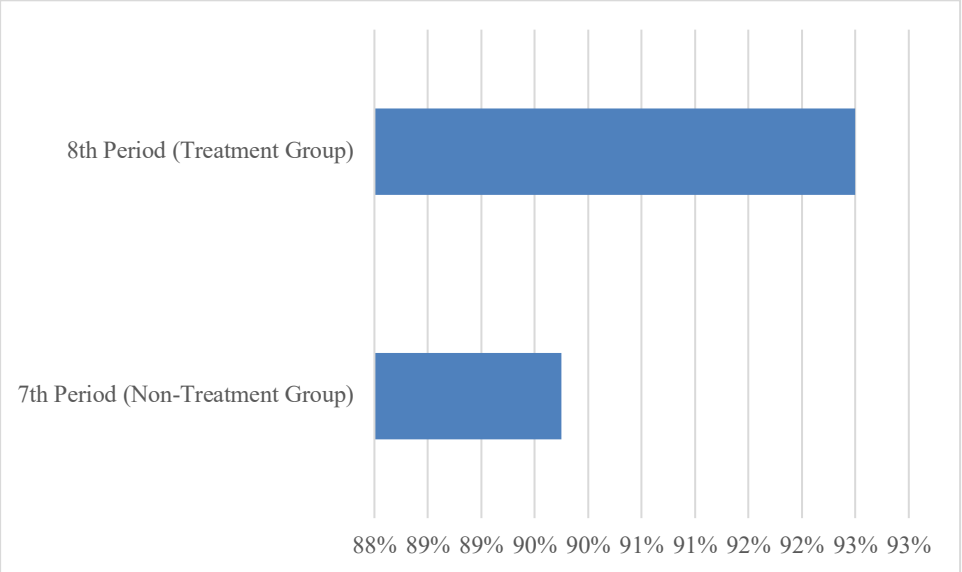

Figure 5 shows that the treatment group scored 2.5% higher than the non-treatment group on standard two pass two.

Figures 4 and 5 show that regardless of being the treatment or non-treatment group, students in my eighth period physics class scored slightly higher on average than students in my seventh period physics class on the second pass for both standards. Before the start of the balanced forces unit, both classes took the Force Concept Inventory. This test, which is used each year in physics, measures mastery of concepts commonly taught in first semester physics. The average for seventh period was 22% while the average for eighth period was 20%. This shows that both classes were very comparable in terms of their initial understanding of forces, and the slight differences seen in short-term retention are likely not attributed to the treatment.

Figure 6

Analysis of Long-Term Retention: Balanced Forces Post-Test Scores

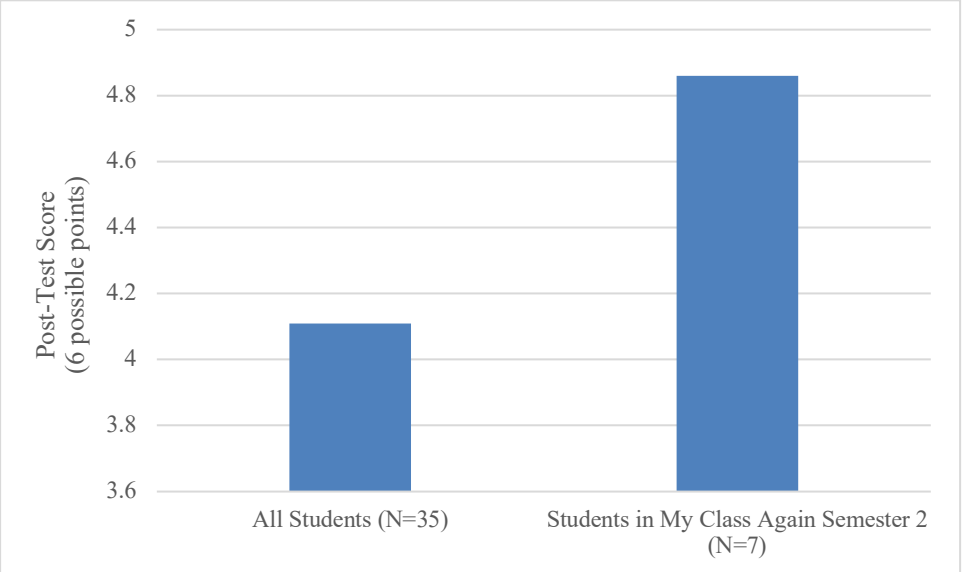

Figure 6 shows how my second semester physics students as a whole compared to the students who were in either my seventh or eighth period class first semester for a balanced forces post-test. The balanced forces post-test, found in Appendix D, covered the main concepts from the Balanced Forces unit. Each question was original in the sense that no students had ever seen it before. The seven students who were in either seventh or eighth period first semester scored an average of 81% on the post-test. The lowest score was 67% and the highest score was 100%. All of my second semester students (N=35) scored an average of 68.5% on the post-test. The lowest score was 33% and the highest score was 100%. Although there are many factors to consider, such as the fact that my second semester students came from five other teachers, this data shows that the treatments may have helped students retain more content.

My takeaways and what I learned from the first cycle allowed me to improve for the second cycle. For example, I had a better handle on getting the formative assessment to students who had absences so they were able to get feedback and take the quiz in a reasonable amount of time. I struggled with this the first time through because if I forgot to give the formative, the timeline for that student got pushed back. I also became very aware that students need time after receiving feedback to work with it. My students who wanted to get extra help often had busy schedules and might be busy with sports, trying to get help for other classes, working after school, and more. It was necessary to give students ample time to sort through the feedback.

I had a very positive experience with giving the formative assessments myself. As opposed to other ways students receive feedback during class, this was very similar to an actual quiz for them. During the administration of the formative assessments, students were quiet and took the task seriously, as they would for something that is graded. Students expressed appreciation for the extra practice and feedback.

INTERPRETATION AND CONCLUSION

The purpose of this project was to determine the effect of formative assessments on my 11th grade physics students' self-confidence, ownership of the material, and retention. The data shows that formative assessments have a positive effect on students' self-confidence and potentially retention of material as well.

A majority of students in both treatment groups agreed or strongly agreed that they were prepared for the summative assessment. Although there are factors out of my

control such as students that struggle with test anxiety, low self-confidence and more, formative assessments gave students the opportunity to identify areas of strengths and weaknesses in an atmosphere where they weren't pressured or being graded. This was a positive outcome of my study.

Students did not access help more or less due to the treatment. The data shows that students who access help outside of the classroom did so regardless of the treatment. This showed me that some students, after receiving feedback that they had made many mistakes, still did not access help. This ownership is part of a much bigger issue of will vs. skill which is an important part of the process that started my inspiration for this project to begin with. How do we engage students who are capable of more, but will not apply themselves? This is an area for future exploration.

Students' retention was viewed using short-term data and long-term data. Short-term, the treatment did not seem to have a significant effect on how well students were able to apply key concepts for the second quiz. Long-term, the data showed that students who were a part of this study scored higher on a balanced forces post-test than students who were not part of this study. Since there were six general physics teachers during this study and students switch teachers and classes after first semester, there are a plethora of factors that may affect long-term retention.

Finally, from the teacher perspective, this study made me a better teacher by being responsive to my students and their needs. I felt more at ease during quiz time, knowing that we had thoroughly practiced everything that students were seeing. This study also helped me get to know my students on a deeper level. I received a lot of responses from

each and every student throughout this process which really allowed me understand their thoughts and viewpoints.

VALUES

My findings indicate that students benefit from, and appreciate, receiving teacher feedback prior to summative assessments. This turned out to be more of a social-emotional outcome than an academic feat. As a science teacher, I am used to hearing from students that math and science classes are very difficult and stressful, and my personal high school experience reflects that as well. A vast majority of my students in general physics are motivated to do well, but aren't necessarily interested in science. Being able to see my students feeling good about what they were doing was one of the highlights from this project.

In future years, I hope to improve on several elements of this study. First, I strive to improve on the quality and quantity of formative assessments in my classroom. Although I believe that students received high quality feedback, the quantity was lacking. It took me a long time to grade each student's work, and it would not be feasible for me to do that several times a week for all my classes. Finding a way to maintain the high quality of the feedback students received while also giving frequent checks for understanding is something to consider for the future. This is where technology can play an important role. There are constantly new ways of providing feedback to students as technology evolves, and that is something I would like to try out as opposed to regular pen and paper feedback. Since I am already familiar with using Canvas and Google Forms, these may be options to consider.

An area for future research is how to involve students' parents/guardians in this process. Something that teachers want to avoid at all costs is the surprised parent because his or her student is receiving a low grade in class. Using formative assessment performance to drive parent communication could have positive impacts on student achievement.

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APPENDICES

APPENDIX A

STUDENT SELF-CONFIDENCE SURVEY

Survey: Formative Assessment

Directions: For each question, select strongly disagree, disagree, neutral (neither agree nor disagree), agree, or strongly agree. Only one option may be selected for each statement. For each question, explain why you answered the way you did.

1) **I looked over the feedback I received from my formative assessment (above) prior to the standards quiz.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

   Why did you answer the way you did in the above question?

2) **The feedback from the formative assessment(s) helped me fix my mistakes.**

   Strongly Disagree Disagree Neutral. Agree Strongly Agree

   Why did you answer the way you did in the above question?

3) **I value getting feedback on my work before a quiz.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

   Why did you answer the way you did in the above question?

4) **I feel prepared for the standards quiz.**

   Strongly Disagree Disagree Neutral Agree Strongly Agree

   Why did you answer the way you did in the above question?

APPENDIX B
STUDENT SURVEY FOR USING OUTSIDE RESOURCES

Survey: Accessing Help Outside of the Classroom **Name:**_____

Period: _____

Select all that you have been to in the past 5 school days:

☐ Physics morning help – M, T, Th, F at 7:00 am in Room 143

☐ Physics peer tutoring – M-F during all lunch periods in the Lit Center and M, T, Th, F at 7 am in the Lit Center

☐ After school tutoring – Wednesdays and Thursdays at 3:15-4:15 in the Learning Commons

☐ I have met with my teacher outside of class

☐ I have not been to any of these places for extra help.

☐ Other (please explain):

For **each of the following**, briefly discuss why you have gone to this place OR why you have chosen not to.

- Physics morning help:

  _____

  _____

- Physics peer tutoring:

  _____

_____

- After school tutoring:

  _____

  _____

- Met with my teacher:

  _____

  _____

- Other (please explain):

  _____

  _____

APPENDIX C

BALANCED FORCES PASS TWO QUIZ

Physics BF 1 Pass 2 & 2 Pass 2 FORM A Name _____ Period ___

Standard	**Score**
BFPM 1: I can identify force as an interaction between a pair of objects. (1)	
BFPM 2: I can distinguish between balanced and unbalanced forces and how they relate to the motion of a system. (2)	

1. A student is pulling two boxes across the floor to the right at a **constant** velocity. Box A does not slip or move on top of Box B (there is NO FRICTION between A and B). The student is pulling ONLY on box B with a rope.
    a. Draw the interaction diagram for the boxes shown below. *(1)*

    b. Draw a free-body (force) diagram for each box. Label each force with (on, by) notation. *(1)* Indicate equal forces with tally marks and write the force equation(s) for each box. *(2)*

FBD Box A	**FBD Box B**
Force equation(s) for Box A	Force equation(s) for Box B

c. Circle the Newton's 3rd Law force-pair interaction in the free-body diagrams above. *(1)*

2. For the following situations, determine if forces are **balanced** or **unbalanced**. *(2)* Draw a free-body (force) diagram for the object in **bold** to support your answer. Label every force with (on, by) notation. *(1)* Indicate equal forces with tally marks. *(2)*

*A **soccer ball** rolls to the left across a field and comes to a stop.*	*A student pulls a **box** to the left. The box remains at rest.*
BALANCED or **UNBALANCED**	**BALANCED** or **UNBALANCED**
*A **hockey puck** glides to the right across a smooth patch of ice at a constant velocity. Assume there is no friction.*	*An archer is shooting a bow and arrow. The **arrow** comes to a stop when it hits the target. Draw your diagram for the moment in which the arrow hits the target.*
BALANCED or **UNBALANCED**	**BALANCED** or **UNBALANCED**

APPENDIX D

POST-TEST FOR SECOND SEMESTER STUDENTS

Question 1

A book rests on a table. Which of the following describes a Newton's 3rd Law force pair?

A) the earth pulls on the book and the table pushes up on the book.

B) the book exerts a force on the table and the earth pulls on the book.

C) the book pushes on the table and the table pushes on the book.

D) A & C

Question 2

If all the forces acting on an object are balanced, the object

A) is at rest.

B) is moving at a constant velocity.

C) is slowing down.

D) could be A or B.

Question 3

If an object starts to accelerate,

A) a balanced force is acting on it.

B) gravity is acting on it.

C) velocity is acting on it.

D) an unbalanced force is acting on it.

Question 4

A force is exerted ON a bottle and an equal and opposite force is exerted BY the bottle. What explains this?

A) conservation of energy

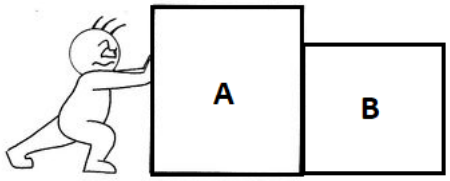
B) Newton's first law of motion

C) Newton's second law of motion

D) Newton's third law of motion

Question 5

For this scenario, the floor is NOT frictionless.



How many forces are acting on Box A?

A) 2

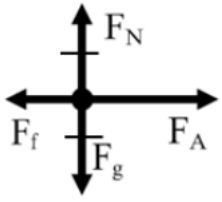
B) 3

C) 4

D) 5

Question 6

What is true about this object?



A) It is moving at a constant velocity.

B) It is accelerating.

C) It is at rest.

D) It is speeding up.

APPENDIX E

TEACHER JOURNAL PROMPTS

1) What went well about this cycle?

2) What would I change next time?

APPENDIX F
INSTITUTIONAL REVIEW BOARD EXEMPTION

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

MONTANA STATE UNIVERSITY

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Administrator:
Cheryl Johnson
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MEMORANDUM

TO: Katherine Katsenes and Walter Woolbaugh

FROM: Mark Quinn Mark Quinn CBJ
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: October 21, 2019

RE: *"The Effect of Formative Assessments on Students' Self-confidence, Ownership of Material, and Retention" [KK102119-EX]*

The above research, described in your submission of October 21, 2019, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).

___ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

___ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

___ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

___ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

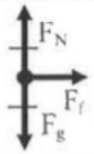
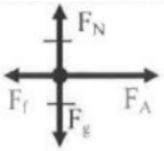
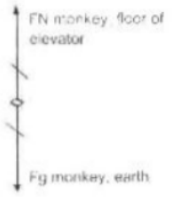
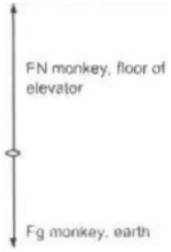
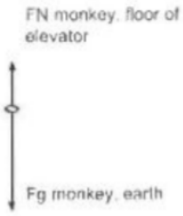
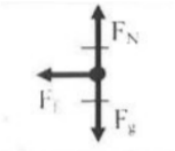
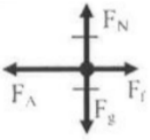
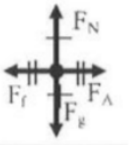
Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX G

STUDENT FORMATIVE ASSESSMENT FOR TREATMENT GROUP 1

BF Formative

1. Circle the free-body (force) diagram(s) that display non-constant velocity.

A		**B**		**C**	
D		**E**		**F**	
G		**H**		**I**	

A sky-diver jumps from a plane and begins falling towards the ground, moving faster as he falls. Assume there is no air resistance. When he is 2,500 feet above the ground, he opens his parachute. He continues falling at constant velocity until he lands.

For the next three questions, circle the correct answer. Explain your reasoning and draw a free-body (force) diagram for each question.

1. Refer to the paragraph above. Before he opens the parachute, the sky-diver is experiencing _____. FBD for sky-diver
    a. Balanced forces
    b. Unbalanced forces
    c. No forces

    Explain your answer:

2. Refer to the paragraph above. After the parachute fully opens, the sky-diver is experiencing _____. FBD for sky-diver
    a. Balanced forces
    b. Unbalanced forces
    c. No forces

    Explain your answer:

3. At the moment the sky-diver lands, the force of the ground on him is _____ the force of him on the ground.
    a. Greater than
    b. Less than
    c. Equal to

    Explain your answer:

APPENDIX H

STUDENT FORMATIVE ASSESSMENT FOR TREATMENT GROUP 2

BF Formative

Scenario: A student pulls a book (mass=1.5 kg) to the left at a constant velocity. The book has a Gatorade bottle (mass=0.5 kg) on top of it.

1. Draw a picture of your scenario. Interaction diagram (optional)

2. Draw a FBD for the block and the bottle. Circle any N3L force-pairs.

FBD Book **FBD Bottle**

3. The student pushes with 10 N of force. Solve for ALL remaining forces. Write the force values next to each force on your FBDs.